THE OSCILLOGRAPHER

VOL. 15, No. 2 SEPTEMBER, 1954

HEART MONITORING

see page 2

"Who and Why"

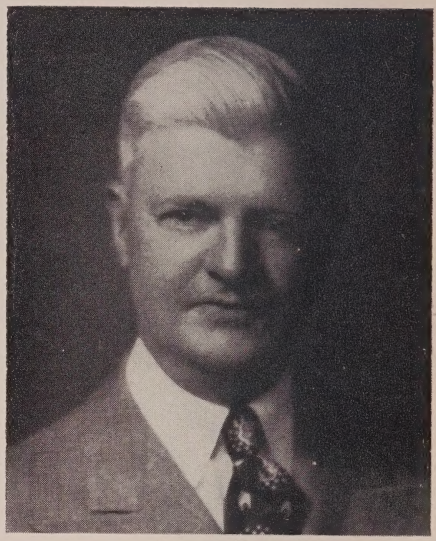
Du Mont Selling Agents

Du Mont's Technical Sales Department is represented in Iowa, Indiana, and parts of Wisconsin, Ohio and Illinois by Alfred Crossley Associates. Alfred Crossley Associates is under the personal guidance of Alfred Crossley himself.

Al Crossley, who has offices in Chicago, Illinois, at 4501 North Ravenswood Avenue, and Dayton, Ohio, at 53 Park Avenue, has had a lifetime of experience in electronics. He was born in Newark, New Jersey, in 1893, and lived in that city long enough to attend public school there. After graduating from high school in Lebanon, Pennsylvania, he attended Naval Electrical School at the Brooklyn Navy Yard. Later he entered the University of North Dakota as a special student majoring in Physics and Radio Engineering.

World War I broke out, and Al, as a Lieutenant (J.G.), was put in charge of radio research at the Bureau of Engineering of the Navy Department. During his stay in the Navy he also supervised construction of Receiving Centers in the Naval Bases at Norfolk, Virginia,

(*Continued on Page* 16)



Alfred Crossley

On the Cover

A Du Mont Type 304-A Cathode-Ray Oscillograph is shown being used in connection with hypothermia techniques (lowering of body temperature) in heart surgery at Children's Hospital, Washington, D. C. The oscillograph is used as a continuous visual monitor of the patient's heart action by surgeons and anesthetists in the operating room, as well as by the cardiologist shown in the left foreground.

THE OSCILLOGRAPHER

A publication devoted exclusively to the cathode-ray oscillograph providing the latest information on developments in equipment, applications, and techniques. Permission for reprinting any material contained herein may be obtained by writing to the Editor at address below.

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TABLE OF CONTENTS

PAGE

"Who and Why" —
Du Mont Selling Agents 2
Features —
Calibrators For The Cathode-Ray Oscillograph 3
How The Cathode-Ray Tube Is Made 10
Applications —
Observing an Arc 8
Miscellaneous —
Important Notice 16

CALIBRATORS FOR THE CATHODE-RAY OSCILLOGRAPH

By: A. W. Russell

No calibration scheme for cathode-ray oscillographs should be used without an understanding of its basic principles and an appreciation of its limitations. The following is a somewhat philosophical article highlighting the pros and cons of various methods of calibration.

Basically, the cathode-ray oscillograph is an instrument for the simultaneous display of two E.M.F.'s. Most often, the horizontal axis of the cathode-ray oscillograph is used to display a voltage which is a linear function of time, while the vertical deflection is supplied by the test voltage with or without amplification. Thus, the unknown signal voltage is displayed as a function of time. In order to specify it completely, it is necessary to provide time and voltage scales for the coordinates. Methods of attaining these goals will be discussed in this article.

Time Calibration

When the sweep of a cathode-ray oscillograph is perfectly linear, we would need to know only its rate, and the calibrated scale in front of the cathode-ray tube would provide a convenient way of sub-dividing sweep speed. However, if we have reason to suspect that the sweep is non-linear, time interval markers should be employed so that the time duration of any section of sweep may be measured.

Since sweeps often are not perfectly linear, it is very desirable to be able to superimpose simultaneous timing markers on the display. These markers may be applied to the Y axis, or they may be applied to the Z axis to blank or to brighten the trace. Y-axis markers need be of comparatively small amplitude, usually five volts or less, but it is often rather difficult to mix the highest frequency marks with the Y-axis signal without impairing one or the other. Z-axis timing markers must be greater in amplitude. As an example, for a Type 5XP-Cathode-ray Tube operating at 12 KV total accelerating potential, 10 to 15 volts is required to brighten, and up to 75 volts to blank the trace.

A choice must be made between brightening and blanking markers. Brightening markers are to be preferred for economy reasons, and because the whole trace is visible. However, they can be used only with sweep repetition rates high enough to provide sufficient reserve brightness to permit adequate additional brightening without defocusing. In other words, if the grid is already at or near zero bias to obtain sufficient brightness to view the sweep, increasing the grid potential further causes no increase in brightness but merely defocuses the beam.

The heart of any simultaneous timing marker generator is an oscillator which oscillates for the duration of the sweep

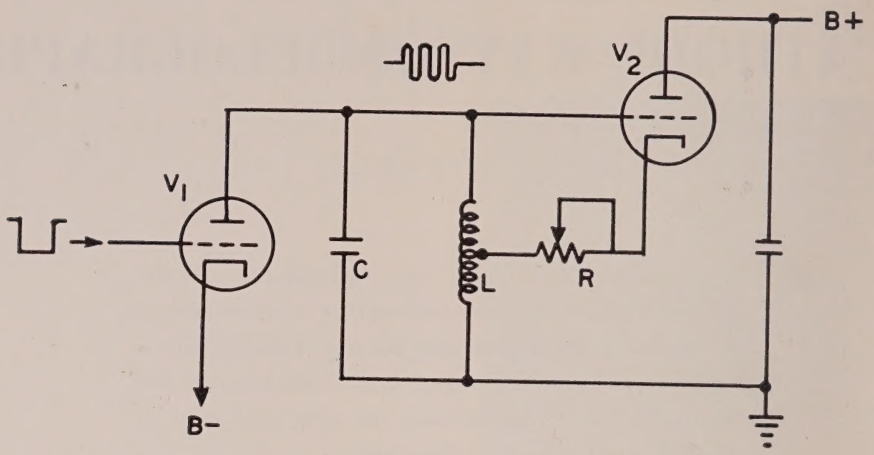


Figure 1. A conventional timing marker generator oscillator circuit. This circuit works well up to 10 megacycles, but above one megacycle it becomes increasingly difficult to maintain a large constant amplitude along with a high duty cycle

time and then decays rapidly to zero to await the initiation of the next sweep. In order to avoid jitter, the oscillations must always start and build up in exactly the same phase each time.

The conventional timing marker oscillator circuit, as shown in figure 1, incorporates an inductance to store energy. The clamp tube V_1 is normally conducting and draws a current I through the inductance L. A negative gate applied to the grid of V_1 cuts off its plate current and an EMF,

$$V = I\sqrt{L/C},$$

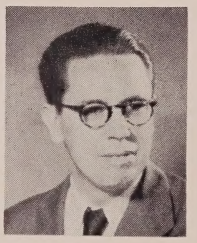
is built up across the tuned circuit LC. The circuit continues to oscillate with a frequency

$$f = \frac{1}{2\pi}\sqrt{LC}.$$

V_2 is connected across LC so as to form a Hartley oscillator, and the resistor R is adjusted to keep the amplitude of the oscillations constant at the amplitude of the first half cycle.

The above circuit works well up to approximately 10 megacycles, but above 1 megacycle it becomes increasingly difficult to maintain a large constant amplitude along with a high duty cycle. A practical disadvantage of the circuit is that at lower frequencies the value of the inductance becomes undesirably large.

A more convenient arrangement is the gated R-C oscillator shown in figure 2. With this circuit an output of 10 volts rms with a fairly good sinusoidal waveform is obtained up to a frequency of 1 megacycle. A three-volt positive gate is required to key the oscillator. In order to obtain reasonable frequency stability against line voltage variations, the feed-



THE AUTHOR

A. Wallace Russell, at the time this article was written, was head of the Low-Frequency Instrument Design Section of the Du Mont Instrument Engineering Division. Wally's 17 years experience in the instrument field, both here and in his native England, qualifies him as an authority on the subject of oscillograph calibration. Since he wrote "Calibrators for Cathode-Ray Oscillographs" for this Oscillographer, he has accepted the position of Market Research Engineer for the Technical Sales Department in Du Mont.

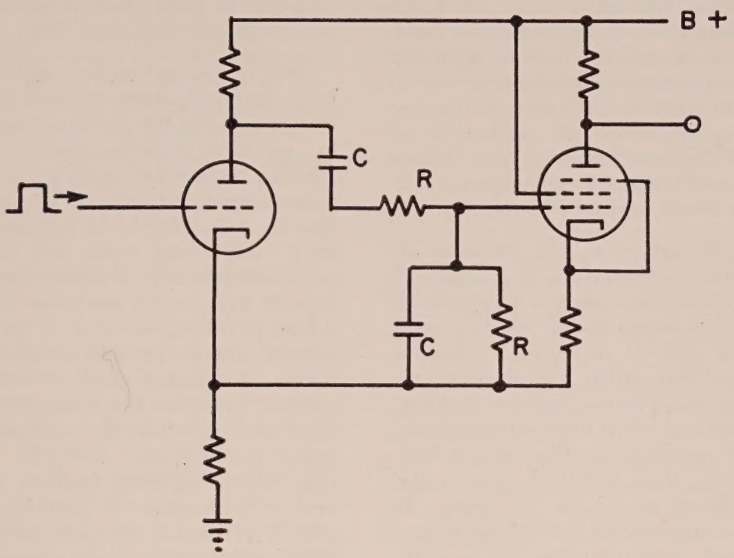


Figure 2. A gated R-C oscillator circuit. An output of 10 volts rms with a fairly good sinusoidal waveform up to one megacycle is available with this circuit

back should be adjusted to give a good sinewave. However, it is necessary here to compromise between frequency stability and amplitude stability, for with a minimum of feedback the oscillator may need up to 10 cycles of operation before a steady amplitude is attained.

A third variety of timing marker generator is shown in figure 3. This might almost be termed a "hot-rod" circuit,

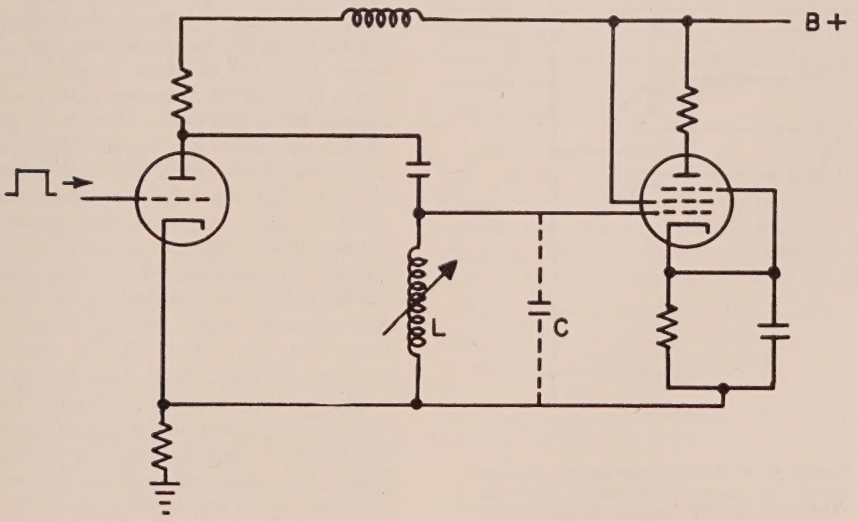


Figure 3. A timing marker generator developed by eliminating from a type of bridge oscillator all elements that have no effect on its operation. The frequency of oscillation (useful to 10 megacycles) is governed by the value of the inductance L and stray capacitance C

for starting life as a kind of Wien bridge oscillator using resistance and inductance elements, it was whittled down by throwing away elements which seemed to have no effect on its operation. The frequency of oscillation is governed by the value of the inductance L and the stray capacitance C. It has been found useful to 10 megacycles.

After discussing a few varieties of timing marker generators, it is apparent that 10 megacycles seems to be a natural limiting frequency above which it gets extremely difficult to build a reliable gated oscillator which will attain maximum amplitude in the first cycle. After much time and effort in experimentation with 100 megacycle oscillators, the fastest built-up time achieved was in the neighborhood of 15 to 20 cycles. It should be emphasized that the frequency of a gated oscillator does not become really stable until 100 or 200 cycles have elapsed. The period of the first 1 or 2 cycles may be in error by as much as 5%, but after about 5 cycles the error is usually less than 1%.

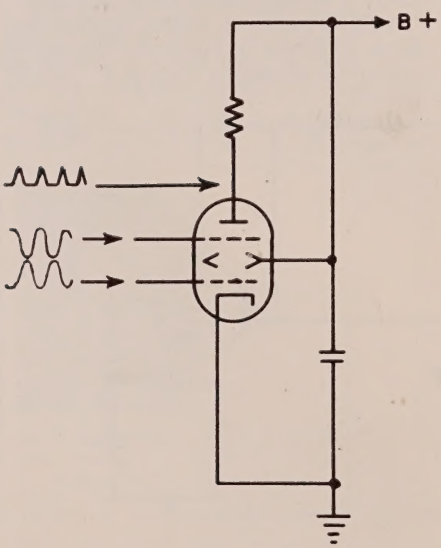


Figure 4. A wide-range pulse shaping circuit for generating timing markers. With this circuit, pulses of plate current appear twice per cycle when both grids go through zero, allowing a gated oscillator to operate at half the normal frequencies

Once a timing marker oscillator has been designed, there remains the problem of shaping the resulting wave trains to produce suitable marker signals. Ideally, the marker signals should have a rectangular waveform. The marks-to-spacing ratio should be between 5% to 20%, depending upon the following consideration: (1) Whether the marker signals are to be used for Y-axis or Z-axis presentation; (2) if the marker signals are to be introduced into the Z-axis — whether they should be employed for beam brightening or blanking; and (3) whether or not higher speed markers are available. For the case where blanking markers are used and it is possible to provide approximately five marks per inch, the optimum duty cycle appears to be approximately 20%.

It has been common practice to use separately switched shaping circuits for each frequency, but for reasons of economy it is obviously advantageous to use an aperiodic device which will operate over a wide frequency range without adjustment. One such pulse-shaping circuit which has certain novel features is shown in figure 4, Applying two sine-waves 180° out of phase to grids 1 and 3 of a type 6BN6, pulses of plate current appear twice per cycle when both grids go through zero. The circuit works well to frequencies slightly above 1 megacycle, and has the advantage that for a given marker frequency the gated oscillator has to operate at only half the normal frequencies. The requirement for the latter characteristic is, of course, two voltages 180° out of phase, but these are generally readily available from an R-C oscillator. Also, the circuit requires a low impedance driver circuit such as a transformer, although a cathode-follower may be used for this purpose. The output pulses from this wave-shaping circuit are small, generally one or two volts in amplitude.

Other possible aperiodic wave-shaping circuits include regenerative amplifiers,

such as direct-coupled multivibrator circuits such as a Schmidt trigger circuit, and amplifiers biased sufficiently beyond cutoff to conduct only on peaks at the desired duty cycle. As with timing marker oscillators, all the above wave-shaping circuits become unduly critical above one megacycle, and circuits peaked for one frequency are necessary above this limit.

Thus far we have considered only the generation of simultaneous timing markers, i.e., timing markers which appear superimposed on the wave form. Sweep calibration can also be effected as a separate operation by substituting for the Y-axis signal a signal of known frequency. Such a standard frequency signal can well be sinusoidal, in which case the Y amplifier will handle all useful calibrating signals for any given instrument. Up to 10 megacycles, adequate signals may be obtained by shock-exciting a tuned circuit and using the resultant damped wave-train. Above 10 megacycles, damped oscillations tend to decay too rapidly and gated oscillators are preferable. However, the problem is still not difficult since the initiation of the sweep can be delayed until the oscillator has reached full amplitude. Using this method, timing signals up to 1000 megacycles have been obtained.

At this point it is worth noting that for photographic calibration, up to the writing rate capabilities of the film, a free-running oscillator of known frequency applied to the Y axis is all that is required. Since only a single sweep is needed for a photographic recording, synchronization of the timing marker generator with the sweep is unnecessary.

There is yet another method of applying a time calibration to a cathode-ray pattern and it is probably the most accurate of all those mentioned previously. This makes use of a strobe, which may be displaced in time relative to the start of the sweep by means of a calibrated delay circuit. Adjusting the delay circuit causes the strobe to move along the X axis. The time interval between two points, for example, the 10% and 90% points on a wavefront, is read off as the difference between two readings of the delay dial setting. The strobe signal may be applied to either the Y axis or the Z axis, whichever is the more convenient. High accuracy may be attained with this method since in this case we are measuring small differences directly rather than absolute values. For example, in the case of the Du Mont Types 256-F and 256-G Cathode-ray Oscillographs, the movable marker employed is accurate to 0.1%. The Du Mont Types 323 and 329 offer the same advantage, in that a 2-inch portion of the sweep can be "expanded" 10 times with respect to the remainder of the sweep. This "notch" expansion is movable as a strobe for accurate time measurements.

Y-axis or Amplitude Calibration

Y-axis or amplitude calibration at first appears to be a much simpler problem than X-axis or time calibration because it is almost always a substitution process. However, this assumption can lead to very serious errors, particularly as the bandwidth of the cathode-ray oscillograph is increased, since the accury of amplitude calibration depends largely on the frequency response of the vertical amplifiers.

Some further sources of error also have to be considered. In general, a signal displayed on the Y axis of a cathode-ray tube first traverses a probe, an adjustable attenuator, an amplifier, then finally the cathode-ray tube itself.

The probe is basically a fixed attenuator which may or may not incorporate a cathode follower impedance transformer. It may introduce errors either by loading the signal circuit, or because its attenuation may vary with freqency.

The attenuator will have its own frequency characteristic which may or may not be a function of attenuation.

The amplifier may give rise to errors (a) because of its gain-frequency char-

acteristic; (b) because its input-output characteristic may not be linear under all conditions, especially a wide-band direct-coupled amplifier which can be biased either side of center to handle uni-directional signals; and (c) because its gain may depend on the line voltage and on the age of its tubes.

The Cathode-ray tube is probably the most dependable component in the Y-axis signal channel. Its deflection sensitivity may vary with line voltage, but in the most modern tubes other errors can be neglected when considering the Y-axis alone.

From the foregoing summary it can be seen that the ideal voltage calibrator for a given application would provide a signal of known amplitude which could be adjusted to equal the unknown signal. The frequency spectrum should be comparable to that of the unknown signal and the source impedance should be the same. The ideal calibrating signal would, of course, be coupled into the oscillograph in exactly the same manner as the unknown signal.

At this point an observation concerning voltage calibrators should be made. It has become standard practice to provide voltage calibrators of low source impedance and to warn the user of the loading effects of the oscillograph input circuit. However, it is at least as important to caution the user of the danger of applying low frequency calibration to signals of much higher frequency. Such calibration will be accurate only over that portion of the frequency range in which the oscillograph has the same gain as it does at the calibrating frequency. At other frequencies the percentage error will be the same as the percentage deviation of the response from the 100% value.

Another note of caution, the voltage calibrator should be sufficiently flexible to facilitate the application of the calibrating signal to the point of entry of the unknown signal.

A final word of warning concerns the provisions for flat-topped calibrating signals. These are certainly easier to see, but they can easily mask overloading or signal clipping due to a fault in the instrument. For this reason, some cathode-ray oscillograph users prefer sine-wave signals. Furthermore, the amplitude of sinewave signals may be checked very readily with a conventional a-c voltmeter having a suitable frequency range.

It should be borne in mind that the foregoing is a somewhat philosophical discussion of oscillograph calibration, and that its aim is to point out that no calibration schemes should be used without an understanding of their basic principles and an appreciation of their limitations. As in every phase of human endeavor, the ideal solution is seldom practicable and sound engineering principles have to be applied to achieve the best compromise between accuracy, convenience and cost. A full description of the methods employed in the Du Mont Type 323 was presented in a previous issue of the Oscilligrapher (Vol. 14 No. 4). The article will amply repay further study in the light of this discussion.

APPLICATIONS

Observing An Arc

In an effort to observe the extent of an arc occurring between a cutting stylus and a copper plate, engineers in the instrument Division of Allen B. Du Mont Laboratories, Inc., applied a Du Mont Type 304-A Cathode-ray Oscillograph across the gap where the arc was occurring. The results were very gratifying.

Referring to the schematic in Figure 1, the problem was this. When the cutting stylus was manually brought in contact with a copper plate, the circuit would be energized, causing the 24-volt, DPDT relay to operate and ener-

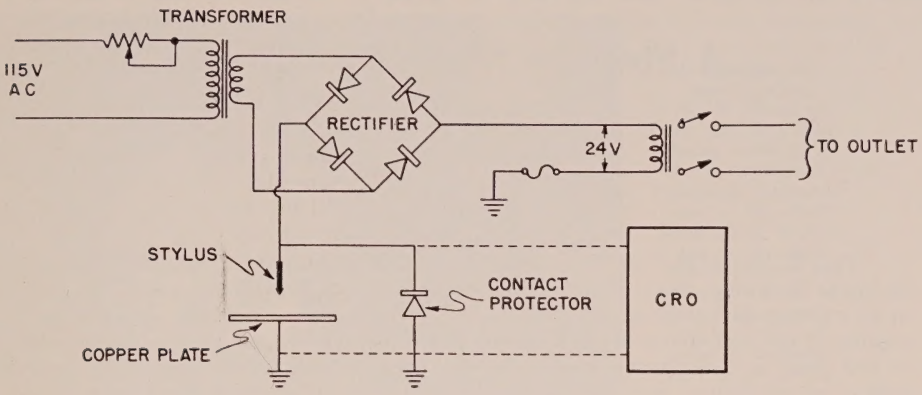


Figure 1. Simplified schematic of a cutting setup used at Du Mont. The oscillograph was used to observe and determine the extent of an arc forming between the stylus and the copper plate

gize the stylus. When the stylus was lifted from the copper plate however, the back EMF would build up voltage in the relay coil and cause an arc that oscillated at high frequency between the copper plate and stylus (see Figure 2). The arc voltage was determined to be approximately 250 volts, and was enough to pit the copper plate.

To eliminate the destructive arc, a Type 8A2PS1 Contact Protector (Federal Telephone and Radio Company, a Division of I. T. & T.) was inserted in the circuit so that it was effectively across the arc. As determined on the oscillograph, the arc-forming voltage-surge was now limited to 40 volts; this value was low enough to avoid pitting. The damping of the high frequency is depicted in the oscillogram in Figure 3. The dot to the left of the picture signifies the normal d-c level.

The sensitivity of the oscillograph to display the waveform in Figure 3 was adjusted to approximately four times that of the sensitivity required for Figure 2 to clearly show the damping effect. Oscillograms were taken with a Du mont Type 296 Oscillograph-record Camera.

Figure 2. The arc caused by back EMF as seen on the oscillograph (left of trace). The arc amplitude is approximately 250 volts

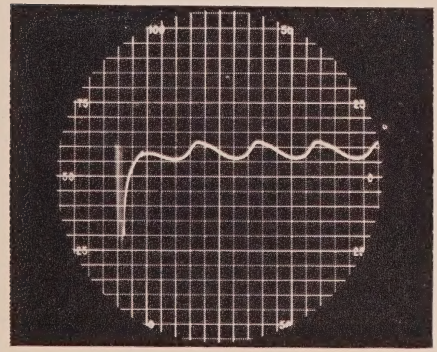
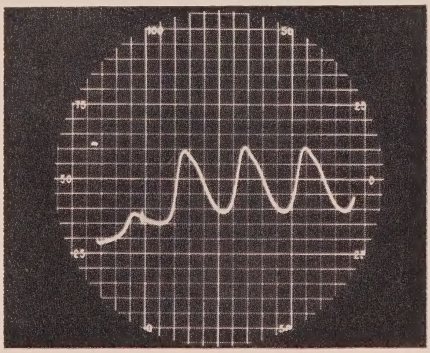


Figure 3. The arc as seen on the oscillograph after the application of the contact protector. Note the dot to the left, signifying the normal d-c level. The signal amplitude was increased approximately four times that of the signal in figure 2 to show clearly the damping effect



How The Cathode-Ray Tube Is Made

A Step by Step Description

By: Morton G. Scheraga

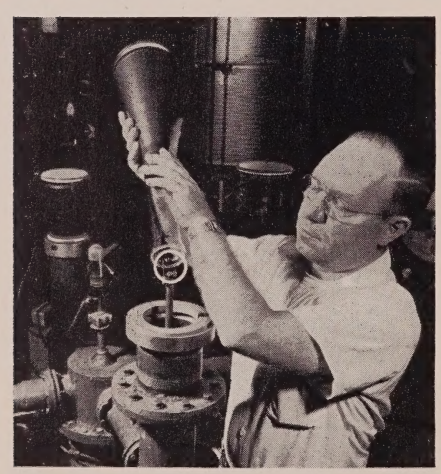
Part II

This is the second set of a series of articles written by Morton G. Scheraga, Assistant Technical Sales Manager, for a different Du Mont publication. In Part I of this series, the incoming parts inspection, various parts assemblies, and the screen coating of the cathode-ray tubes were discussed. To describe the metallization process in this issue, it is necessary to go back into the screening operation description and note a few variations. For Part I, See OSCILLOGRAPHER, Vol. 15, No. 1.

Metallization

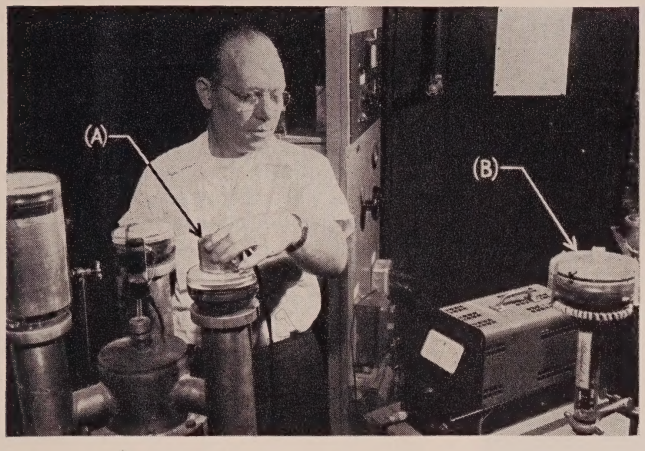
It will be recalled that during the settling of the screen with the gel-settling technique, the gel cushion and phosphor mixture are settled in the tube with its face downward. At this point in the screening operation, if a tube is to be metallized, a lacquer is laid down on the liquid surface and allowed to dry.

The liquid is then decanted from the tube in the same manner as for conventional screening. During the decanting, the liquid pours out from under the hardened lacquer layer, and the layer itself moves down the tube until all the liquid is removed. The lacquer surface then completely covers the screen material. The lacquer bridges the gaps between the discrete screen particules, and provides a relatively smooth surface on which the aluminum can be deposited. From this point, up to the time of depositing the aluminum layer, the screening procedures are the same as described previously, except for an additional inspection step to examine the lacquer surface.



To metallize a tube, a tungsten heater (note circle) is inserted in the position later occupied by the electron gun, and the tube is evacuated. A specific amount of aluminum for each tube type is boiled off in the tube. The aluminum vapor fills the tube and deposits on the screen and inner walls

To desposit the aluminum layer on top of the lacquer, a tungsten heater is inserted in the position occupied later by the electron gun and the tube is evacuated. With the heater is a predeterminted amount of aluminum required for a particular size tube and desired metal layer thickness. The heater is raised to a temperature at which the aluminum boils off. The aluminum vapor fills the tube and deposits on the screen and inner walls. Those parts of the tube which should not be covered with aluminum, such as the post-accelerator area of the Type 5XP-B, are covered with temporary shields during the metallization operation. The thickness of the aluminum layer that is deposited determines the "crossover" potential.



A specially designed probe (A) is placed on the face of a tube being metallized for a continuous thickness measurement of the aluminum being deposited. A standard tube (B) with an aluminum layer of known characteristics is always at hand for calibration of the probe

Since the thickness and uniformity of the aluminum layer are very important for uniform light output and optimum operation of the tube, an additional check is made on the amount of aluminum deposited. At Du Mont, a specially designed probe, which is in effect a "grid-dip" meter, is placed on the outside surface of the glass faceplate during the depositing of the aluminum. The inductance of the metal layer changes with thickness, and the meter is calibrated for the required thickness. To check the meter's calibration, a standard tube with an aluminum layer of known characteristics is kept at hand at all times.

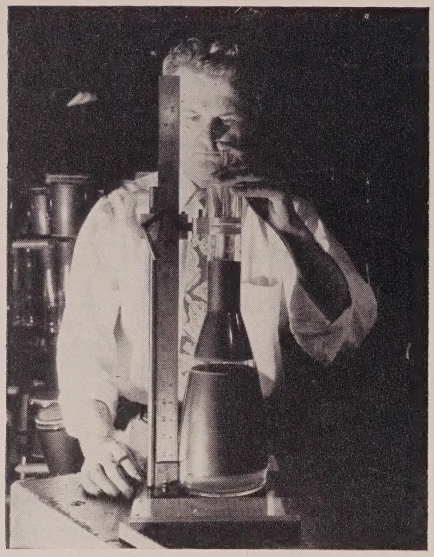
After the aluminum coating is laid down, the tube moves on in the assembly process as with a conventionally screened type.

Why are Cathode-ray Tubes Metallized

The crossover potential of a metallized tube is the accelerating potential at which its light output equals that of an unmetallized screen. Below this crossover potential, the aluminum layer actually impedes the penetration of the electron beam to the screen, causing a loss in light output. Above the crossover potential, the electrons have enough energy to penetrate the metal layer. In addition, the aluminum surface acts as a mirror, which reflects forward a large amount of light from the screen which would ordinarily be lost inside the tube. Within maximum tube ratings, the higher the metallized tube is operated above the crossover potential, the greater is the gain in light output compared to that of a non-metallized tube operating at the same potential. It is possible to double the light output of a tube solely by metallization and operating at potentials of ten to twelve thousand volts.

In normal practice, the crossover potential is held within the range of 5.5 to 6.0 kv. Unless requested to do otherwise, this is the crossover potential at which the tubes are metallized. It is possible to metallize for as low as 5 kv, but this is the lowest limit at which a uniform layer can be deposited without "holes" and without excessive manufacfacturing shrinkage. If the tube is to be operated at very high potentials, for example 20 kv, it is advisable that the tube manfacturer know of it. It would then be possible to build special tubes by raising the crossover potential with a thicker and still better aluminum mirror, and gain a still greater increase in light output.

One important advantage gained by metallizing is the laying down of a uniformly conducting layer on top of the screen, and thus preventing the building up of spurious screen charges. Such charges can be bothersome, particularly when transients are studied, and the



First step in the sealing operation is to mark the tube neck at a fixed position from the screen for any given tube type. This is done on the precision machined fixture in which the tube sets. Two lines are marked on the neck, to which the operator aligns the gun position, to prevent parallax errors

charge from one trace may actually distort the pattern of a succeeding transient. For example, the position of the target in a PPI (plan-position-indicator) display may be erroneously indicated because charges built up from preceding scans may effect the targets produced in succeeding scans. Thus, for applications where optimum precision of spot location or best fidelity of wave shape is required, it is good practice to metallize the screen and design the equipment accordingly to operate the tube above the crossover potential.

Still another advantage of metallization is the virtual elimination of heater glow, which does not penetrate the aluminum mirror. Heater glow may be a problem when photographic recordings of an uncontrolled transient are made and the shutter has to be left open for long periods of time.

The Sealing Operation

One of the most important factors to control in sealing the gun into the bulb is the distance between the gun and the screen. This distance is particularly critical in tight-tolerance tubes for it affects the deflection factor, the scanning limits on the screen, and the spot size.

The first step in the sealing operation is to mark the neck of the bulb at a fixed distance from the screen. This is done in a precision-machined fixture in which the bulb rests. Two lines are marked on the neck to serve as a reference point to which the operator aligns the top surface of the first grid. Two lines are used instead of one to prevent parallax while the operator sights the position of the gun inside the neck.

In inserting the gun inside the neck the operator must also take into account the angular position of the deflecting plates with respect to any contacts on the bulb, such as deflecting plate of anode connectors. To do this, he aligns a reference plane on the gun with a particular contact on the bulb. Coaxial positioning of the gun inside the neck is maintained by the spring arrangement at the deflection plate end of the gun known as the "spider." The position of the cathode end of the gun is maintained by the glass stem to which the gun is attached and which is sealed to the neck near the base of the tube.

With the gun roughly positioned inside the bulb, the entire assembly is placed into an electric annealing oven to pre-heat the metal, glass rods, the glass stem in the gun structure, and the glass bulb. The pre-heating prevents the developing of strains during the sealing operation.

The pre-heated assembly is then placed in the face upward position on the automatic sealing machine. This is a machine which has a series of rotating fixtures, mounted on a rotating turntable that automatically indexes each fixture past a series of flames located around the turntable. Each flame is successively hotter than the one before it, except the last one.

The tube is placed in the fixture and adjusted to bring the gun exactly to the reference points marked on the glass neck. The bulb and gun are then locked

into position for the rest of the sealing operation, thus holding the critical dimensions during the fusing of the glass stem to the neck.

Up to twelve tubes can be handled at once on sealing machines. A tube starting it's sealing cycle passes first in front of the coolest flame. The fixture holding the tube is constantly rotated to give equal distribution of heat around the area of the neck where the weld is to be made. (See figure 3).

At pre-set time intervals, the tube is automatically indexed in front of each flame until the next to last, and hottest, flame. While the tube rotates in front of this flame, the weld is completed and the excess glass drops off. The tube is then indexed to the last flame which anneals the seal.

An interesting thing about the sealing operation is that while automatic machinery and precision fixtures can be used, the adjustment of the flames remains a fine art. Not only must the proper temperature, shape and length of each flame be adjusted, but also their distance from—and angle—with respect to the glass is important. The quality and strength of the weld as well as absence of strains are determined by the flame adjustments. Also affected is the

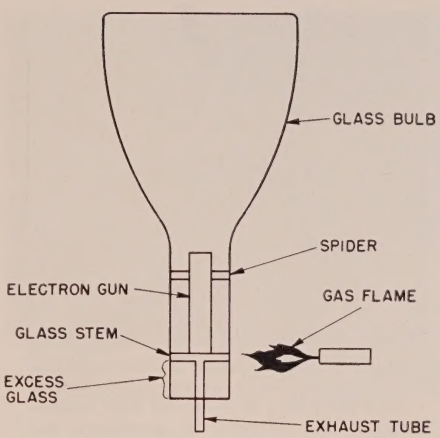
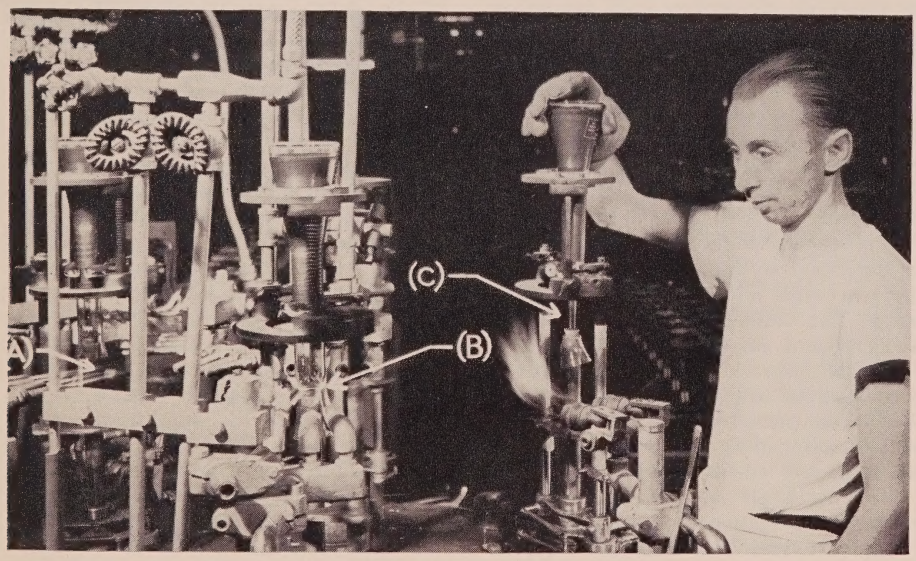
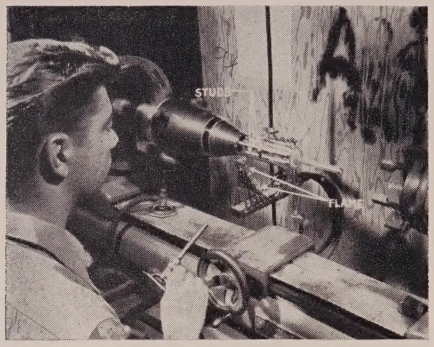


Figure 3. In the sealing-annealing process, a gas flame is directed at the neck of the tube bulb just below the inserted glass stem. The excess glass is burned off at this point, and the stem sturdily welded to the neck



The automatic sealing machine has a series of rotating fixtures mounted on a turntable that automatically positions the tubes through a series of flames. Each flame is hotter than the previous one, except for the last — annealing flame. Shown on this machine (used for custom-made tubes) at (A), the tube is entering the second hot flame; at (B) the cut and sealing has been practically completed; at (C) the sealing and annealing cycle is completed and the tube removed



Studs of special tubes are brought out through the neck of the tube, rather than the base, to minimize lead capacitance. The operator is annealing the glass around the studs, in an operation called the "second sealing", after the cut was made to bring the studs through

shape of the weld, which is critical, if the base is to set properly. The best cements will not hold the base to the glass unless the seal contour is shaped correctly.

Evacuating the Tube

Two types of machines are employed to evacuate the industrial type tubes. In one system, several tubes are pumped simultaneously by a single pump. The other and newer system employs the "in-line" exhaust. Both systems are capable of the same degree of quality as long as proper techniques and "know-how" are applied. The in-line system represents the more modern approach.

Referring to figure 3, note that an exhaust tube is attached to the glass stem. The cathode-ray tube is placed, face upward, on the pumping machine with the exhaust tube inserted into a vacuum-tight chuck. Each tube goes on a separate pump, which is carried on a small trolley that moves constantly on a completely enclosed track.

The car itself is worthy of note. It carries two pumps; the mechanical "rough" pump, and a diffusion pump in series with it. Leads are connected to the tube filament, and brushes are so located at the top of the car as to pick up heater power at intervals along the track. The car also carries an rf-bombardment coil which surrounds the neck of the tube in the region of the electron gun. Power for the rf-coil is again picked up by brushes at the proper point along the track.

The speed at which the cars are pulled by the "locomotive" at the head of the train, the power fed to the heater and rf coil, and the temperature of the baking ovens through which the cars pass are pre-set for a given type of tube and screen, and are then automatically controlled from a master control board. All of these parameters have been established empirically, and constitute part of the "know-how" of top quality tube manufacturing.

With the vacuum-tight chuck closed, the pumps begin exhausting the tube. Evacuation continues as the car moves into a long baking oven that gradually increases the temperature of the tube at a precisely controlled rate. The baking drives off gases trapped in the fluorescent screen material. These gases are evacuated constantly by the pumps.

The precise control of the temperature rise in the ovens is important to prevent implosions and avoid strains in the glass. About once a week a tube is run through the system with several thermocouples attached to it to measure the uniformity of control of the ovens. A continuous plot of the temperature cycle is made on a multi-channel recorder, and if necessary, adjustments are made to gain uniformity.

The speed at which the cars move through the ovens depends on the screen type. Cascaded screens, such as the P7, require much longer baking to drive out gases and are usually run separately; however, it is possible to run single-layer screens on the same trains at the relatively slow P7 speed.

After the tube reaches its maximum temperature, it is gradually cooled in another bank of ovens. Near the end of the temperature and exhaust cycle, the heater is energized to drive off any gases from the cathode material. Simultaneously the rf-coil is energized to bombard the gun structure and heat it to the point where all the metal elec-

trodes have a faint cherry glow. This outgases the entire gun assembly.

Even after evacuating by the pumps, some gas remains in the tube. To absorb these gases, the "getter" is then flashed by an rf-probe brought near the getter pod mounted on the gun structure.

The cathode-ray tube is now ready to be closed ("tipped") off. A gas flame is directed at the exhaust tube while pumping continues. The tube gradually closes near the stem and a leak-proof seal is made.

It remains now only to thread the leads through the base, which is filled with cement and attached to the end of the glass neck. The base area of the neck is then baked to set the cement and then the leads are soldered to the base pins.

The completed tube now moves to the automatic aging racks. Here, the cathode is activated and a moving raster pattern put on the screen. The next—and final—step is testing; completing the manufacturing process of the simpler type cathode-ray tubes.

Mono-Accelerator Tubes

Certain design considerations necessitate a slightly altered bulb-shape for mono-accelerator tubes. The gun structure of a mono-accelerator tube is longer than that of, for example, the type 5ADP. Bearing in mind that the gun structure is supported by a spider which contacts the glass neck near the end of the gun assembly, with a longer gun this spider support would fall beyond the neck region and in the flared part of the bulb.

The new bulb shape has a longer neck and a wider flare angle. This is necessary in order to keep the overall length

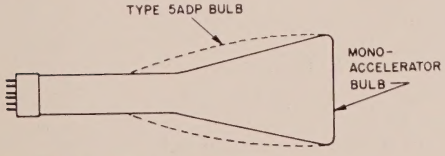
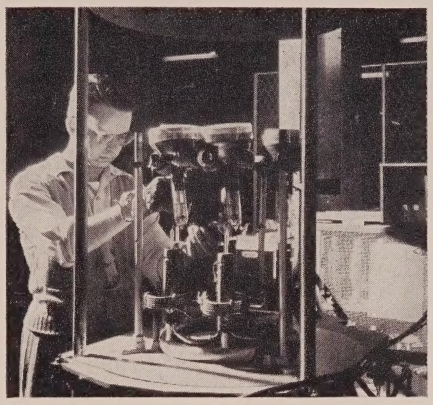


Figure 4. The electron-gun of the mono-accelerator tubes were too long to get proper support in the old shaped tube bulb, so the longer necked, wider-flare angled tube shape was evolved



Exhausting and "tipping off" a small quantity of Type 5AHP Cathode-ray Tubes. Tipping off is still an art that must be accomplished manually by experienced personnel. Larger runs of tubes are exhausted and tipped off on a more automatic, in-line type of machine

of the bulb the same. The new and old bulbs are compared in figure 4.

The two greatest assets of this new shape are simpler shape and reduced volume. With a properly designed magnetic shield fitted to this longer neck, additional space is available in an instrument for components mounted near the cathode-ray tube. The straight sided, conical shape is possible with mono-accelerator tubes because there are no post-accelerator field problems. Since the new bulb equals or is smaller in all dimensions than the old bulb, there are no mechanical problems in adapting the tube to existing instruments.

Cathode-ray tube-making is such a fine art, that the greater part of the knowledge available on cathode-ray tube manufacturing has been learned only through years of diligent research and experimentation; further knowledge of the art will be learned in the same manner.

Cathode-ray tube manufacturing consists of a series of complex, yet coordinated steps. These steps have been continually made easier by cleverly designed machinery. Even though cathode-ray tubes are intricate objects, this increasing trend towards removal of

possible human errors has improved their quality to the point that they are now used in the most precise computers and measuring devices confidently.

Acknowledgment

We want to acknowledge the help of Messrs. William Hyde and Howard Grossbohlin of the Cathode-ray Tube Division, along with those gentlemen mentioned in the last issue of the Oscillographer, for their cooperation in the preparation of this article.

"Who and Why"

(*Continued from Page* 2)

and Great Lakes, Illinois. In 1919, and during the next nine years, Al was Division Engineer at the Naval Research Laboratory, Washington, D. C. While at the Naval Research Laboratory, he did a great deal of pioneering in the Piezo-Electric Crystal technique field (for which there are at least 12 patents under his name). His section of the research lab was responsible for making the first crystal controlled transmitter. In 1928 he went to work with Steinit Radio as Chief Engineer, and was Chief Engineer with Howard Radio from 1929 to 1932.

Al started his own private practice as a Consulting Engineer in 1933. His work involved electronic and radio engineering research investigations and product design besides his duties as a patent-case expert. His early pioneering in the powdered iron tuning device field from 1933 on has earned him at least 10 patents. Al holds 50 U. S. patents at last count, and about 50 foreign patents.

Despite his heavy schedule, Al Crossley has found time to author seven papers published in *Proceedings of the IRE*, and four papers or articles in other electronic journals. He is a Senior Member of the IRE (having served as Chairman of the Chicago Section in 1935), is a member of Rotary, Chicago Yacht and Michigan Shore Club, and was Chairman (1932-33) of the Receiver Section of the Radio Manufacturers Association. He is a Registered Professional Engineer, number 6948, in Illinois.

Mr. Crossley's association with Du Mont is one of the longest in Du Mont's history. The prestige his representation has given Du Mont in the mid-west is one of the very many assets Du Mont has gained through this association.

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